

### **REMARKS**

This amendment is responsive to the Office Action dated March 23, 2004. Applicants have amended claims 1, 3, 10 and 12 and added new claims 19-27. Claims 1-27 are now pending.

#### **Amendments to the Specification**

In the Office Action, the Examiner objected to the Specification and indicated that the word “servopositioning” should be written as “servo positioning.” The Examiner indicated that appropriate correction is required.

Attached herewith is a substitute specification under 37 C.F.R. 1.121(b)(3). In particular, a redlined copy and a clean copy of the amended specification are being provided in accordance with 37 C.F.R. 1.121(b)(3) and 37 C.F.R. 1.125(b) and (c). Please replace the original specification with the substitute specification. No new matter has been introduced in the substitute specification.

Applicants note that the substitute specification does not include any amendments to the claims, as the corresponding changes to the claims are being provided via the claim amendments of this response.

#### **Amendments to the Drawings**

In the Office Action, the Examiner objected to the drawings as failing to comply with 37 C.F.R. 1.84(p)(4) because reference character “42” was used to designate both a notch filter and a demodulator. Attached herewith is a replacement drawing sheet, which amends FIG. 4 to address the Examiner’s concerns. In particular, the demodulator circuit has been amended to be identified by reference character “43.” This amendment is consistent with Applicants’ specification as originally filed. Applicants respectfully request acceptance of the replacement drawing sheet and entry of the amendment to FIG. 4.

#### **Amendments to the Claims**

Applicants have amended the claims to replace the word “servopositioning” with “servo positioning,” as suggested by the Examiner. This amendment is unrelated to patentability.

### **Claim Rejections**

In the Office Action, the Examiner rejected claims 1-18 under 35 U.S.C. 112, first paragraph, as failing to comply with the written description requirement. Specifically, the Examiner indicated that each of the independent claims set forth producing position error signals at a sampling rate and increasing the bandwidth of the timing signal above the sampling rate. The Examiner indicated that this combination of features cannot be reasonably understood from the written specification. The Examiner also appears to have further rejected claims 3 and 12 as failing to meet the written description requirement, indicating that the term "playback null" is not adequately defined in the specification.

Applicants respectfully traverse these rejections. The pending claims clearly meet the written description requirements of 35 U.S.C. 112, first paragraph for at least two reasons. First, the claims themselves, as originally filed, are part of the specification and, therefore, the claims themselves reasonably convey that Applicants were in possession of the claimed invention at the time of filing. See, e.g., M.P.E.P. 2163.06 section III. In addition, the body of the specification does recite the features of Applicants' claims, notwithstanding the Examiner's statements to the contrary. Accordingly, one skilled in the art of data recording would have no difficulty appreciating that Applicants were in possession of the invention, as claimed, at the time the application was filed.

M.P.E.P. Section 2163.02 sets forth the standard for Determining Compliance With the Written Description Requirement. As stated in that section,

To satisfy the written description requirement, an Applicant must convey with reasonable clarity to those skilled in the art that, as of the filing date sought, he or she was in possession of the invention, and that the invention, in that context, is whatever is now claimed. The test for sufficiency of support in a parent application is whether the disclosure of the application relied upon 'reasonably conveys to the artisan that the inventor had possession at that time of the later claimed subject matter.' *Ralston Purina Co. v. Far-Mar-Co., Inc.*, 772 F.2d 1570 (Fed. Cir. 1985) (quoting *In re Kaslow*, 707 F.2d 1366 (Fed. Cir. 1983)).

Applicants' claims meet this standard by themselves, as these claims were originally presented at the time of filing. Accordingly, there can be no question that originally filed claims meet the Written Description requirement because the originally-filed claims are part of the specification. See also M.P.E.P. 2163.06 section III.

In addition, the body of Applicants' specification does recite the features of Applicants' claims, notwithstanding the Examiner's statements to the contrary. In particular, page 4, lines 6-9 of Applicants' specification describes produce position error signals at a sampling rate and increasing the bandwidth of the timing signal above the sampling rate. In addition, the "playback null" feature is discussed in detail at page 4, line 25 to page 5, line 15. Examples of a playback null are even provided in this section of

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Applicants' specification. Accordingly, for these additional reasons, Applicants submit that the Examiner's Written Description rejections are improper, and strongly dispute the Examiner's statements that the playback null of the servo positioning system are not clearly supported in Applicants' specification.

**New Claims**

Applicants have added claims 19-27 to the pending application. Applicants believe that new claims 19-27 are in condition for immediate allowance.

**Conclusion:**

The amendments filed herewith should overcome the Examiner's objections to the drawings and the specification. Moreover, the Examiner's rejections under 35 U.S.C. 112, first paragraph, are improper for at least the reasons outlined above. New claims 19-27 have been added.

Applicants believe that all claims in this application are now in condition for allowance. Applicants respectfully request reconsideration and prompt allowance of all pending claims. Please charge any additional fees or credit any overpayment to deposit account number 09-0069. The Examiner is invited to telephone the below-signed attorney to discuss this application.

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PATENT

Attorney Docket No. 10289US01

## TIME-BASED ~~SERVOPOSITIONING~~SERVO POSITIONING SYSTEMS

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### FIELD OF THE INVENTION

This invention concerns systems and methods for time-based ~~servopositioningservo~~ servo positioning in the context of linear data recording media such as magnetic tape.

### BACKGROUND OF THE INVENTION

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Modern data storage systems use ~~servopositioningservo~~ servo positioning (or “servo”) systems to guide their recording and playback components with respect to a recording medium, and thus enable high track density, which increases data storage capacity. Errors in the ability to follow the ~~servopositioningservo~~ servo positioning signals on the medium can cause unacceptable reductions in storage capacity, recording/playback rates, and other parameters that are important to consumers (and

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thus to system manufacturers).

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One type of servo patterns or formats for linear magnetic tape recording systems employs so-called time-based servo techniques, examples of which are disclosed in US Patents 5,689,384; 5,930,065; and 6,021,013 (all of which are incorporated by reference in their entireties). Commercial magnetic tape drives such as the IBM model 3570 and drives known under the names “Ultrium” and “Accelis,” as described by the Linear Tape Open consortium, use time-based ~~servopositioningservo~~ servo positioning systems.

The advantages of time-based servo systems include very wide dynamic range; inherent track identification; low DC centerline error; and the ability to qualify position error signal (PES) validity by the amplitude of the servo signal. Disadvantages include extreme sensitivity to tape speed during writing; sensitivity to high frequency speed error during reading; and poor scalability to very small track pitches.

## SUMMARY OF THE INVENTION

In general terms, the invention may be embodied in time-based ~~servo positioning~~ servo positioning systems, methods, and formats, or in data recording media used in association with the same, and therefore this disclosure should be understood in that regard even if only an example of a particular embodiment is described in detail. Similarly, this disclosure should be understood to apply to either analog or digital signals, in accordance with principles known in the art. Thus, the terms "signal," "data," and the like may be used interchangeably, and should be understood to apply to either analog or digital representations of information.

In the most basic embodiment of the invention, a ~~servo positioning~~ servo positioning system for a data recording system is used in combination with a linear data recording medium, preferably magnetic recording tape. Written or recorded on the medium are a timing reference (for example, a high frequency AC "pilot tone") and a conventional time-based servo signal. Appropriate circuitry is separately responsive to the two signals so they can be separated from each other. The circuitry produces position error signals by sampling the time-based servo signal at a sampling rate, and also increases the bandwidth of the timing reference signal above that sampling rate. In the preferred embodiment, the two types of signals are written onto the same location of the recording medium, but the high frequency pilot tone signal is written such that its frequency lies in a playback null of the time-based ~~servo positioning~~ servo positioning system. Any technique for accomplishing this is suitable, but in the most preferred

embodiment the two signals are recorded at different azimuth angles with respect to each other (*i.e.*, relative to the playback head of the system).

### **BRIEF DESCRIPTION OF THE DRAWINGS**

5 The accompanying drawings show a particular embodiment of the invention as an example, and are not intended to limit the scope of the invention.

Figure 1 is a schematic diagram of one embodiment of the invention.

Figures 2a, 2b, and 3 are schematic views of geometric aspects of the embodiment of Figure 1. Figure 2b is an enlarged view of the portion of Figure 2a indicated by the circle designated 2b.

10 Figure 4 is a schematic diagram of another aspect of the embodiment of Figure 1.

Figures 5 and 6 are schematic diagrams of a preferred embodiment of the invention.

### **DETAILED DESCRIPTION**

15 In general terms, the invention can be embodied in an entire system of data recording and playback, including the combination of a drive and a linear recording medium; or as only the recording medium portion of such a system; or as methods for recording or playing back data in combination with the data recording medium. Thus, while the following description may occasionally focus on only one aspect of an entire  
20 system (*e.g.*, the recording medium alone) to disclose the preferred embodiment of the invention, this is by way of example only, and not a limitation on the scope of the invention. It should be understood that the full scope of the invention includes other aspects of the system depending on the circumstances, such as combinations of the

medium and drive, and methods of using such combinations or relevant portions of them.

The time-based servo system described in US Patents 5,689,384 and 6,021,013 is somewhat immune to speed error (or time-based error) in playback by the use of a reference pulse to compare against the PES (Position Error Signal) pulse. The system is only somewhat immune, because as the frequency of the speed error increases up to the sample rate of the PES system itself, the natural immunity generated by the reference normalization procedure decreases.

Data recording systems using tape media can have considerable time-based error (also known as instantaneous speed variation, or ISV) at frequencies approaching commercially standard PES sample rates. The invention improves the time normalization performance (and thereby the immunity to ISV) of linear data recording systems by effectively increasing the reference time-based bandwidth until it is greater than the PES sample rate.

Figure 1 is a schematic view of one recording system embodiment suitable for this approach, using (for purposes of illustration only) magnetic recording tape as the preferred type of linear recording medium.

Recording system **20** comprises supply reel **21**, tape **22**, pilot tone recording head **23**, time-based servo write head **24**, verify head **25**, and take-up reel **26**. An AC bias signal **27** is the input to pilot tone recording head **23**. A current pulse signal **29** is the input to time-based servo write head **24**. Verify head **25** produces verify signal **30** that typically passes through a conventional preamplifier (not shown) to become input signal **41** of Figure 4 (described below).

Figures 2a and 2b schematically show a full-width servo band of height **h** superimposed on a "sea" of high-density pilot tone **2** produced by pilot tone recording

head 23, which is subsequently used for playback speed tracking. The time-based servo pulses 6 produced by time-based servo write head 24 overwrite this tone. By way of example only, the servo pattern has five pulses 6 per sample 7. The high-density tone is largely unaffected by the servo pulses because the servo pulses are written using a return-to-zero technique meaning the write current is mostly turned off. In general, the high frequency signal 2 is recorded at a wavelength such that its frequency lies in a playback null of the time-based ~~servo positioning~~ servo positioning system.

In the preferred embodiment, the two signals are recorded at different azimuth angles with respect to each other. Referring additionally to Figure 3, for a given read track width  $T_w$  and a given slant angle  $\theta$ , there is a natural spatial frequency null at a wavelength  $\lambda_{HF}$  proportional to the read track width and the tangent of the slant angle  $\theta$ , or  $\lambda_{HF} = T_w * \tan(\theta)$ . Thus, placing the pilot tone in the azimuth null of the time-based servo enables both signals to be available after suitable filtering. For example, given a read track width of 5 micrometers and an angle  $\theta$  of  $\pm 8$  degrees,  $\lambda_{HF}$  occurs at the reasonable density of 72,300 flux changes per inch (fci). This density is well within the capability of a tape and a head designed for >150kbpi data recording. At two meters/second media speed, this density corresponds to a frequency of 2.8MHz, easily enabling a phase locked loop tracking bandwidth above 50kHz, or approximately 10 times the typical ISV resonant frequency of the medium. These are examples only and not limitations on the scope of the invention.

A preferred system to fully utilize this signal structure is shown schematically in Figure 4 as circuitry 40. Circuitry 40 receives an input signal 41 produced by the conventional read head preamp (not shown) as described above. This signal is input to both a band reject ("notch") filter 42 and a band pass filter 44. Notch filter 42 eliminates the high density pilot tone component but has little effect on the time pulse, because the filter notch is at the same frequency as the natural azimuth loss notch. The filtered time pulse is thereafter processed normally, as described in US Patent

6,021,013, with one crucial difference; the measurement time base normally derived from an external clock is derived from the high-density signal.

Specifically, the portion of the signal that passes through band pass filter **44** is the input to a phase locked loop (PLL) **46** that produces a measurement time base  
5 signal **50** for the time-based demodulator circuit **43**. The band pass is only wide enough to pass the signal and its anticipated FM sidebands, *e.g.* for the case above,  $2.8\text{MHz} \pm 100\text{kHz}$ . This narrow 200kHz bandwidth is more than eleven decibels quieter than the regular data channel, and therefore this reference tone signal has good  
10 signal -to-noise ratio, even when recorded at a low level. (The smaller read track width of the servo read head circuitry makes this narrow band high frequency signal perhaps only 8db better than the read channel at the same density.) The PLL locks onto this frequency and generates a frequency tracking reference clock for the time-based servo detector circuit. This clock could be any rational multiple of the recorded tone. For example, for the rational multiple of 107 to three, the reference clock signal will be  
15  $2.8\text{ MHz} \times 107/3 = 99.8\text{ MHz}$ .

The high density signal actually serves at all times as a reference, and therefore has some advantages over the traditional “B interval” reference as described in US Patent 6,031,013, particularly at column 7, line 30 to column 8, line 2. First, the need for the “B interval” is eliminated altogether and replaced by the need to know when the  
20 “A interval” (or measurement period), as described in the same patent, begins. This enables a higher PES sample rate, because eliminating the reference measurement reduces constraints on the design of the format. Second, since the time-based reference is known at the same time that the PES measurement is known, and because a sampling delay appears to the servo system as if it were a phase lag, there is little PES sampling  
25 phase delay, by a factor of as much as one-half the sample time. This enables higher servo performance.

In the preferred embodiment of this scheme, and as taught in US Patent 6,021,013, multiple PES bursts are recorded together, such as in groups of four or five.

The spacing between these pulses should be such that the pulses fall on unique phases of the high frequency tone. For example, if the first pulse in a group of four pulses falls  
5 on the zero degree phase of the high frequency signal, the second pulse should fall on the [N cycles plus] ninety degree phase of the next pulse. Similarly, the third pulse should fall on the [N cycles plus] 180 degree phase, and the fourth pulse at the [N cycles plus] 270 degree phase. Since the PES is calculated by taking the average of these four values, any possible bias caused by the high frequency tone may be averaged  
10 out according to known principles.

In another preferred embodiment of the invention, the pilot tone is modulated with a (preferably double) side band AM component without affecting the timing functionality, provided the modulation does not approach 100% negative, which would negate the pilot tone signal entirely. For example, as illustrated in Figure 5, pilot tone  
15 **27** is formed by combining an AC bias signal **28** (for example, a sine wave signal in the range of eighty to three hundred kfc) and modulation carrier **34** (for example, a sine wave signal in the range of approximately twenty to one hundred kfc). The modulation content may comprise linear position (or "LPOS") data, or auxiliary data (e.g., manufacturing data) as indicated at **31**, and general purpose data such as  
20 synchronization signals and error correction/detection data as indicated at **32**. Other content may include encoding data as indicated at **33**, including "biphase" or Manchester encoding, NRZ, NRZI, PR4 and other known encoding techniques; however, quadrature amplitude ("I & Q") modulation schemes may not be desirable because the primary timing task of the carrier signal is adversely affected. Manchester  
25 encoding provides the advantage of simplified decoding due to the simpler embedded clock structure.

The resolution of the linear position data may be as coarse as 10cm to as fine as 1cm, although greater resolution requires greater bandwidth which is undesirable because it reduces the robustness of the signal. Assuming digital modulation bandwidth (double sided) of the pilot tone carrier of approximately 10 KHz and a tape speed of 2 m/s, Manchester encoding would encode 2.5 kbps or 1.25 bits/mm; thus, 125 bits would be encoded in a span of 10 cm, which is sufficient for an accurate LPOS signal. Other more sophisticated encoding schemes could produce as much as 50 bits/cm in the same bandwidth.

Figure 6 is a schematic diagram of the receiver for this embodiment. The AM signal first passes through band pass filter **44** and is an input to the phase locked loop **46**, which tracks its frequency and phase. The primary use of this input is to time the time-based servo pulses, as in the embodiment described above, and also to synchronously demodulate the AM signal by use of an analog multiplier **47**. The output of analog multiplier **47** passes sequentially through a low pass filter **49**; a detector **51**; a channel code demodulator **52**; appropriate encoding **53** for data words, sync signals, and error correction codes, as applicable; and suitable LPOS counters and auxiliary text memory **54**. The result is an output signal **55** that is transferred to the drive controller of the system (not shown).

We claim:

1. A servopositioning system for a linear data recording system, comprising in combination:
  - a) a linear data recording medium, upon which are recorded a time-based servo signal, and a timing reference signal having a bandwidth; and
  - b) circuitry, separately responsive to the timing reference and time-based servo signals, for
    - (i) producing position error signals by sampling the time-based servo signal at a sampling rate; and
    - (ii) increasing the bandwidth of the timing reference signal above the sampling rate of (i).
2. The system of claim 1, in which the measurement time base for producing the position error signals is derived from the timing reference signal.
3. The system of claim 1, in which the timing reference signal's frequency lies in a playback null of the time-based servopositioning system.
4. The system of claim 3, in which the timing reference signal and the time-based servo signal are recorded at different azimuth angles with respect to each other.
5. The system of claim 3, in which the time-based servo signal comprises at least one sample, each sample comprising at least two pulses, the spacing between the pulses being such that the pulses fall on unique phases of the timing reference signal.

6. The system of claim 5, in which there are four pulses in each sample, each of the four pulses falling ninety degrees out of phase with each other, and a first pulse falling on a zero degree phase of the timing reference signal.
7. The system of claim 1, in which the timing reference signal further comprises a side band amplitude modulated component.
8. The system of claim 7, in which the timing reference signal further comprises a double side band amplitude modulated component.
9. The system of claim 7, in which the modulated component comprises at least one of linear position data, manufacturing data, synchronization data, error detection data, error correction data, and encoded data.
10. A method of servopositioning for use with a data recording system, comprising:
- a) writing on a linear data recording medium a time-based servo signal, and a timing reference signal having a bandwidth;
  - b) producing position error signals by sampling the time-based servo signal at a sampling rate; and
  - c) increasing the bandwidth of the timing reference signal above the sampling rate.
11. The method of claim 10, further comprising deriving the measurement time base for producing the position error signals from the timing reference signal.
12. The method of claim 10 in which writing the timing reference signal comprises writing an AC frequency that lies in a playback null of the time-based servopositioning system.

13. The method of claim 12, in which the writing comprises writing the timing reference signal and the time-based servo signal at different azimuth angles with respect to each other.
14. The method of claim 12, in which the time-based servo signal comprises at least one sample, each sample comprising at least two pulses, the spacing between the pulses being such that the pulses fall on unique phases of the timing reference signal.
15. The method of claim 14, in which there are four pulses in each sample, each of the four pulses falling ninety degrees out of phase with each other, and a first pulse falling on a zero degree phase of the timing reference signal.
16. The method of claim 10, in which the writing further comprises writing a side band amplitude modulated component in the timing reference signal.
17. The method of claim 16, in which the writing further comprises writing a double side band amplitude modulated component in the timing reference signal.
18. The method of claim 16, in which the writing further comprises writing in the modulated component at least one of linear position data, manufacturing data, synchronization data, error detection data, error correction data, and encoded data.

**TIME-BASED ~~SERVO~~POSITIONING SERVO POSITIONING SYSTEMS**

**Abstract of the Disclosure**

~~Servo~~positioning Servo positioning systems, methods, formats, and data  
5 recording media used in association with the same, employing additional timing  
reference information to improve immunity to time-based errors caused by  
instantaneous speed variations.